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Impact of practice patterns in shunt use during carotid endarterectomy with contralateral carotid occlusion

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Purpose: **This study investigated the association between surgeon practice pattern in shunt placement and 30-day stroke/death in patients undergoing carotid endarterectomy (CEA) with contralateral carotid occlusion (CCO).**
Methods: **Among 6379 CEAs performed in the Vascular Study Group of New England (VSGNE) between 2002 and 2009, we identified 353 patients who underwent CEA with CCO and compared the 30-day stroke/death rate with 5279 patients who underwent primary, isolated CEA with a patent contralateral carotid artery. Within patients with CCO, we examined the 30-day stroke/death rate across the reason for shunt placement and two distinct surgeon practice patterns in shunt placement: surgeons who selectively used a shunt (≤95% of CEAs) or routinely used a shunt (>95% of CEAs). We used observed/expected (O/E) ratios to provide risk-adjusted comparisons across groups.**
Results: **Of 353 patients with CCO, 118 (33%) underwent CEA without a shunt, 173 (49%) underwent CEA using a shunt placed routinely, and 62 (18%) had a shunt placed for a neurologic indication. Rates of 30-day stroke/death across categories of reason for shunt use were no shunt, 3.4%; routine shunt, 4.0%; and shunt for indication, 4.8% ($P = .891$). The risk of 30-day stroke/death was higher for surgeons who selectively placed shunts (5.6%) in all their CEAs and lower for surgeons who routinely placed shunts (1.5%, $P = .05$). The risk of 30-day stroke/death was >1 in patients undergoing selective shunting (O/E ratio, 1.4; 95% confidence interval [CI], 1.1-1.7) and <1 for surgeons who placed shunts routinely (O/E ratio, 0.4; 95% CI, 0.2-0.9). Stroke/death rates were lowest when individual surgeons' intraoperative decisions reflected their usual pattern of practice: 1.5% stroke/death rate when "routine" surgeons placed a shunt, 3.4% when "selective" surgeons did not place a shunt, and 7.6% stroke/death rate for "selective" surgeons who placed a shunt ($P = .05$ for trend).**
Conclusions: **The risk of 30-day stroke/death is higher in CEA in patients with CCO than with a patent contralateral carotid artery. Surgeons who place shunts selectively during CEA have higher rates of stroke/death in patients with CCO. This suggests that shunt use for CCO during CEA is associated with fewer complications, but only if the surgeon uses a shunt as part of his or her routine practice in CEA. Surgeons should preoperatively consider their own practice pattern in shunt use when faced with a patient who may require shunt placement. (J Vasc Surg 2012;55:61-71.)**

Surgical decision making for patients with severe carotid atherosclerosis is complicated by the presence of a contralateral carotid occlusion (CCO).[1-4] Fewer than 10% of carotid endarterectomies (CEAs) are performed in patients with CCO, limiting the power of most studies to analyze uncommon events such as perioperative stroke or death. Evaluation of potential methods of risk reduction during CEA with CCO is also challenging, because of the inherent variation in patient risk factors, such as symptomatic or asymptomatic presentation, and surgical technique such as the use of eversion CEA or patch angioplasty.

Despite these challenges, many believe that using an intraoperative shunt is important for stroke reduction during CEA in patients with CCO. Proponents argue that shunt use ensures global perfusion, as evidenced by electroencephalography (EEG) and stump pressure measurement.[5] Further, large clinical series have shown excellent outcomes when shunts are placed for CEA in the setting of CCO. However, many surgeons argue that shunts are not routinely necessary, even in patients with CCO.[4,6-8] This conclusion is justified by similarly large case series of CEAs that demonstrate equivalent rates of stroke with and without a shunt in CEAs in patients with and without CCO.[9] But in many of these series, CEA is performed by a high-volume surgeon or group of surgeons who rarely place a shunt for any reason. Whether these results can be generalized to broader populations of surgeons and patients is uncertain.

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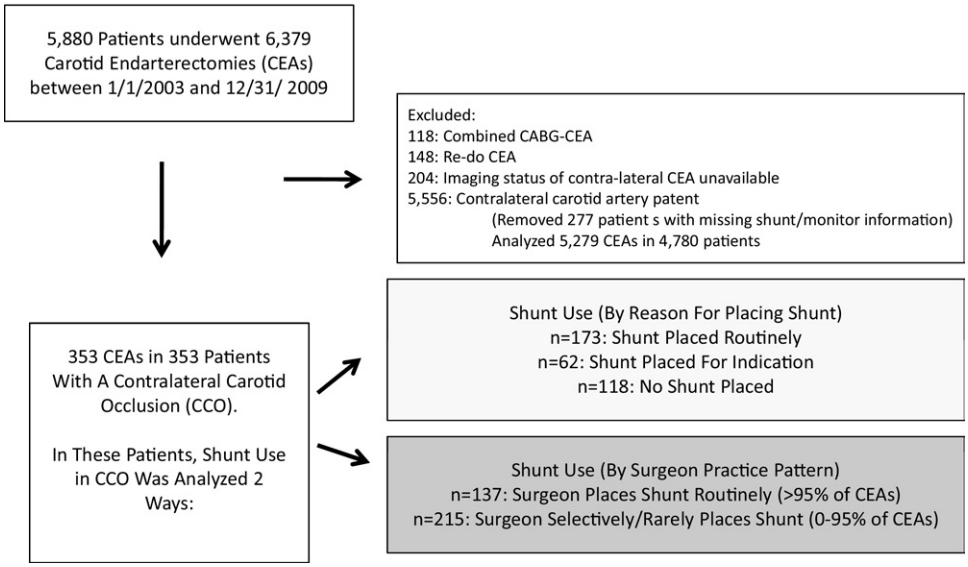

Fig 1. Cohort formation.

To study the outcomes and optimal management of a large group of patients undergoing CEA in the setting of CCO, we used data from the Vascular Study Group of New England (VSGNE). We examined the outcomes of patients undergoing CEA in the setting of CCO, with a focus on evaluating the effect of different surgeon practice patterns regarding shunt use within the academic and community centers that participate in this regional registry.

METHODS

The Institutional Review Board at Dartmouth Medical School reviewed and approved our study protocol. Within the VSGNE, data were prospectively collected by 74 surgeons and associated staff in 12 hospitals (http://www.vsgne.org). Hospital data were collected for each patient and periodically audited against claims data to ensure entry of all patients. Follow-up data were collected at subsequent outpatient evaluation, with data from the visit closest to 1 year after surgery entered into the database. Further details on this database have been published previously,[10] and others are available at http://www.vsgne.org.

Patients. Between January 1, 2003, and December 29, 2009, 5880 patients underwent 6379 primary CEAs in New England at one of the 12 centers participating in our registry (Fig 1). Of the 6379 CEAs, 204 patients (3.1% of the total) did not have imaging information (duplex ultrasound, computed tomography [CT], or magnetic resonance imaging [MRI]) available at the time of surgery and were excluded from the analysis. Patient data were entered into the registry preoperatively, at discharge, and at the 1-year follow-up. Mean interval of follow-up was 13.5 months (95% confidence interval [CI], 12.6-14.5 months).

We excluded 148 patients (2.3% of the total) who underwent redo CEA and 118 who had combined coronary artery bypass grafting (CABG)/CEA (1.8% of the total). Our study cohort consisted of 353 patients with a CCO documented by preoperative imaging. Of the 5556 CEAs with a patent contralateral carotid artery (performed in 5057 patients), details on shunt placement or monitoring information was unavailable in 227 patients (4%). Therefore, our comparison cohort consisted of 5279 CEAs performed in 4780 patients with a patent contralateral carotid artery.

Definitions and exposure variables. The unit of analysis was the operation. Patients were evaluated for preexisting medical comorbidities, and these data were prospectively entered into the registry by specifically trained surgeons, nurses, or clinical data abstractors. More than 70 clinical and demographic variables were collected for each patient. Our data set was audited for completeness of procedural submissions using International Classification of Diseases (9th Revision) data from each center.[10,11]

The main exposure variable was the presence of a CCO, and the secondary exposures were the type of shunt placed and surgeon practice patterns in shunt placement. Demographic data and the incidence of patient-level comorbidities are outlined in Table I. CEA was categorized as conventional or eversion. Primary vs patch closure of the endarterectomy and other descriptions of the operative technique, such as anesthesia type, anticoagulant use, were recorded as well as completion study use.

Examination of the decision to place a shunt. First, with the patient and procedure as the unit of analysis, we categorized shunt use by the manner in which the shunt was placed (Fig 1). In the VSGNE registry, shunt use during CEA is categorized as not used (none), placed

Table I. A, Characteristics of patients undergoing carotid endarterectomy (*CEA*) characteristics by presence or absence of a contralateral carotid occlusion (*CCO*)

	CEA performed				
	With CCO (n = 353)		*Without CCO (n = 5279)*		
Variable	*No.*	*%*	*No.*	*%*	P
Patient characteristics					
Male sex	282	72.5	3210	59.3	<.001
Right side	197	50.6	2585	49.0	.445
Non-white race	3	0.8	61	1.2	.319
Urgency					
Elective	312	88.4	4720	89.5	.086
Urgent	41	11.6	515	9.8	
Emergency (n = 389)	0	0.0	41	0.8	
Age, years					
<40	0	0.0	3	0.1	.117
40-49	15	4.3	117	2.2	
50-59	54	15.3	638	12.1	
60-69	103	29.2	1630	30.9	
70-79	133	37.7	2024	38.3	
80-89	47	13.3	830	15.7	
≥90	1	0.3	37	0.7	
Smoking (former or current)	318	90.1	4153	78.9	<.001
Diabetes	104	29.5	1623	30.8	.616
Percent of patients with creatinine >1.8g m/dL	43	12.2	443	8.4	.013
Dialysis	0	0.0	38	0.7	.077
Hypertension	317	89.8	4570	86.7	.027
β-blockers	297	84.6	4337	82.5	.313
Coronary disease	126	35.7	1709	32.4	.371
Prior CABG or coronary intervention	118	33.4	1662	31.5	.686
Congestive heart failure	28	8.0	385	7.3	.557
Ipsilateral degree of stenosis					
<50%	1	0.3	36	0.7	.321
>50%	6	1.7	79	1.5	
>60%	12	3.4	230	4.4	
>70%	62	17.6	1128	21.4	
>80%	268	76.1	3753	71.3	
Occluded	3	0.9	35	0.7	
Contralateral degree of stenosis					
<50%	0	0.0	2983	58.5	<.001
>50%	0	0.0	606	11.9	
>60%	0	0.0	543	10.6	
>70%	0	0.0	601	11.8	
>80%	0	0.0	369	7.2	
Occluded	353	100.0	0	0.0	
Symptom status					
Cortical symptoms (TIA or stroke)	91	25.8	1964	37.2	.003
Ocular symptoms	30	8.4	816	15.3	<.001
Ipsilateral vertebrobasilar symptoms	17	4.9	130	2.5	.006
Preoperative medication regimen					
No antiplatelet agent use	38	10.8	585	11.1	.020
Aspirin only	240	68.0	3851	72.9	
Clopidogrel only	15	4.2	146	2.8	
Aspirin, clopidogrel, or both	60	17.0	687	13.0	
Statin use	274	77.8	3850	73.0	.043
Operative characteristics					
General anesthesia	330	93.5	4637	87.9	<.001
Shunt use (by procedure)					
No shunt placed	118	33.4	2823	53.5	<.001
Routine shunting	173	49.0	2209	41.9	
Shunting placed for indication	62	17.6	224	4.6	
Monitoring that prompted shunt					
Electroencephalogram	57		192		
Awake patient	3		14		
Other (eg, stump pressure)	2		15		

Table I. A, Continued

	CEA performed				
	With CCO (n = 353)		*Without CCO (n = 5279)*		
Variable	*No.*	*%*	*No.*	*%*	P
Shunt use by surgeon practice pattern					
Selective shunter	215	60.9	3267	62.1	.809
Routine shunter	138	39.1	1992	37.9	
Technical aspects of CEA					
Eversion endarterectomy	34	9.7	564	10.7	.427
Patch angioplasty	298	84.4	4474	84.8	.999
Protamine	153	43.5	2481	47.1	.461
Completion study	130	36.8	1751	33.2	.032

CABG, Coronary artery bypass grafting; *TIA,* transient ischemic attack.

because of routine practice (routine), or placed for a specific indication, such as EEG changes with clamping, observed neurologic changes in an awake patient, or low carotid stump pressure (shunt for indication), Thus, for each CEA, shunt use was categorized as none, routine, or for indication.

Because we sought to examine surgeon practice patterns in shunt use, we then categorized each surgeon according to his or her practice pattern in CEA by using two mutually exclusive practice patterns: surgeons who routinely (>95% of all their CEAs) or selectively use a shunt (≤95% of all their CEAs). These thresholds were established after examination of the practice patterns in shunt use (Fig 2) and a review of current literature.[12-15] Other thresholds were examined in sensitivity analyses of 30%, 50%, 80%, and 90% shunt use.

Outcome measures. Our main outcome measure was 30-day stroke or death after CEA. In crude analyses, we compared unadjusted rates of 30-day stroke or death after CEA across patients with and without CCO. Further, within those patients who underwent CEA in the setting of a CCO, we compared crude rates of 30-day stroke or death across type of shunt use (none, routine, shunt for indication) as well as across surgeon practice pattern (routine or selective).

Multivariable model to adjust for preoperative/risk of 30-day stroke or death. After determining the crude rates of 30-day stroke or death, we compared the crude rates across groups with and without CCO, using observed-to-expected (O/E) ratios. These O/E ratios were generated by dividing the observed 30-day stroke or death rate by the predicted 30-day stroke or death rate for each group. These predicted risks were generated at the patient level, based on preoperative patient characteristics, using our VSGNE-specific CEA risk prediction model. This model uses preoperative patient characteristics (urgent need for surgery, symptom status, congestive heart failure, age, and antiplatelet therapy) to predict the risk of stroke or death ≤30 days after CEA.[11] We used this model because it was derived from >3000 CEAs in the VSGNE and has been internally and externally validated. We then compared predicted and actual rates to provide each group's O/E ratio with surrounding 95% CIs. All analyses were performed using Excel (Microsoft, Redmond, Wash) and Stata software (Stata Corp, College Station, Tex).

RESULTS

Patient characteristics. Overall, patients with CCO were more frequently male (73%) and most commonly aged between 70 and 79 years. Nearly all (99%) were white (Table I), and 89% were former or current smokers; 91% had hypertension, 30% had diabetes, and 23% had a history of chronic obstructive pulmonary disease. By symptom status, 54% were symptomatic (39% ipsilateral, 15% contralateral or nonspecific) and 46% were asymptomatic. Further details about the characteristics of the cohort are available in Table I.

Patients who underwent CEA for CCO differed from the remaining CEA patients in the VSGNE registry in several ways. Patients with CCO were more commonly male (73% vs 59%), more likely to have a smoking history (90% vs 79%, $P < .001$), more likely to have chronic renal insufficiency (12% vs 8%, $P = .013$), and more likely to have hypertension (91% vs 87%, $P = .02$). Although patients with CCOs tended to have more comorbidities, 39% were symptomatic compared with 55% of the non-CCO patients ($P = .001$, Table I). Lastly, patients with CCO were less likely to undergo surgery without a shunt (33%) compared with 54% of non-CCO CEAs performed without a shunt ($P < .001$).

Among patients with CCO, there were several differences in shunt use by patient characteristics (Table I, *B*). For example, patients in whom a shunt was placed for an indication were more likely to be symptomatic preoperatively (37%) than those in whom no shunt (18%) or routine shunting (27%) was used ($P < .01$). Further, patients who underwent urgent operations were more likely to receive a shunt for indication (26%) vs patients undergoing elective CEA (16%; $P < .018$).

Rate of 30-day stroke or death. The rate of 30-day stroke or death was higher in patients in the setting of a CCO

Table I. B, Characteristics of patients with contralateral carotid occlusion (*CCO*) undergoing carotid endarterectomy (*CEA*) by type of shunt (no shunt, routine shunt, or shunt for indication)

	CEA with CCO (n = 353)		*No shunt (n = 118)*		*Routine shunt (n = 173)*		*Shunt for indication (n = 62)*		
Variable	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	P
Patient characteristics									
Male sex	282	79.8	92	77.9	122	70.5	43	16.7	.299
Right side	197	55.8	56	47.5	110	63.5	31	50.0	.063
Non-white race	3	0.8	0	0.0	2	0.6	1	1.6	.391
Urgency									
Elective	312	88.4	112	94.9	149	86.1	51	82.3	
Urgent	41	11.6	6	5.1	24	13.9	11	17.7	
Emergency	0	0.0	0	0.0	0	0.0	0	0.0	.018
Age, years									
<40	0	0.0	0	0.0	0	0.0	0	0.0	
40-49	15	4.3	3	2.5	7	4.1	5	8.0	
50-59	54	15.3	19	16.1	26	15.0	9	15.3	
60-69	103	29.2	42	35.6	48	27.8	13	20.9	
70-79	133	37.7	42	35.6	66	38.2	25	40.3	
80-89	47	13.3	12	10.2	25	14.5	10	16.1	
≥90	1	0.3	0	0.0	1	0.6	0	0.0	.535
Smoking (prior or current)	318	90.1	108	91.5	152	87.9	58	93.6	.356
Diabetes	104	29.5	34	28.8	47	27.2	23	37.0	.333
Creatinine >1.8%	43	12.2	13	11.0	18	10.4	12	19.4	.162
Dialysis	0	0.0	0	0.0	0	0.0	0	0.0	.999
Hypertension	317	89.8	108	91.5	153	88.4	56	90.3	.687
β-blockers	297	84.6	102	86.4	137	80.1	58	93.6	.034
Coronary disease	126	35.7	50	42.4	56	32.4	20	32.3	.179
Prior CABG or coronary intervention	118	33.4	50	42.4	46	26.6	22	35.5	.018
Congestive heart failure	28	8.0	5	4.2	16	9.3	7	11.3	.166
Ipsilateral degree of stenosis									
<50%	1	0.3	0	0.0	1	0.6	0	0.0	
>50%	6	1.7	0	0.0	6	3.5	0	0.0	
>60%	12	3.4	3	2.5	9	5.2	0	0.0	
>70%	62	17.6	23	19.5	29	16.9	10	16.1	
>80%	268	76.1	92	78.0	124	72.1	52	83.9	
Occluded	3	0.9	0	0.0	3	1.7	0	0.0	.106
Symptom status									
Cortical symptoms (TIA or stroke)	91	25.8	21	17.8	47	27.2	23	37.1	.016
Ocular symptoms	30	8.4	6	5.0	19	10.9	5	8.0	.394
Ipsilateral vertebrobasilar symptoms	17	4.9	3	2.5	11	6.4	3	4.8	.594
Preoperative medication use									
No antiplatelet agent	38	10.8	13	11.0	20	11.5	5	8.0	
Aspirin only	240	68.0	90	76.3	106	61.3	44	71.0	.997
Clopidogrel	15	4.2	3	2.5	8	4.6	4	6.5	.673
Aspirin, clopidogrel, or both	60	17.0	11	9.3	42	24.3	7	11.3	.083
Statin	274	77.8	97	82.2	134	77.9	43	69.4	.143
Operative characteristics									
General anesthesia	330	93.5	101	85.6	170	98.3	59	96.2	.001
Shunt use by surgeon practice pattern									
Selective shunter	215	60.9	116	98.3	37	21.4	62	100.0	.001
Routine shunter	138	39.1	1	0.8	136	78.6	0	0.0	
Technical aspects of CEA									
Eversion endarterectomy	34	9.7	24	20.5	2	1.2	8	12.9	.001
Patch angioplasty	298	84.4	84	71.2	165	95.4	49	79.0	.001
Protamine	153	43.5	29	24.6	106	61.3	18	29.5	.001
Completion study	130	36.8	41	34.8	69	39.9	20	32.3	.479

CABG, Coronary artery bypass grafting; *TIA,* transient ischemic attack.

than in those patients who underwent CEA without CCO (4.0% vs 1.9%, $P < .007$, Table II). Across the 353 patients undergoing CEA in the setting of a CCO, 14 strokes and three deaths occurred within the first 30 days after surgery. The three deaths occurred in patients who had experienced a postoperative stroke. Among 5279 patients undergoing CEA who did not have a CCO, 100 strokes and nine deaths occurred, and all but three deaths were stroke-related.

Rate of 30-day stroke or death by shunt use. Within the patients with CCO, there were no significant

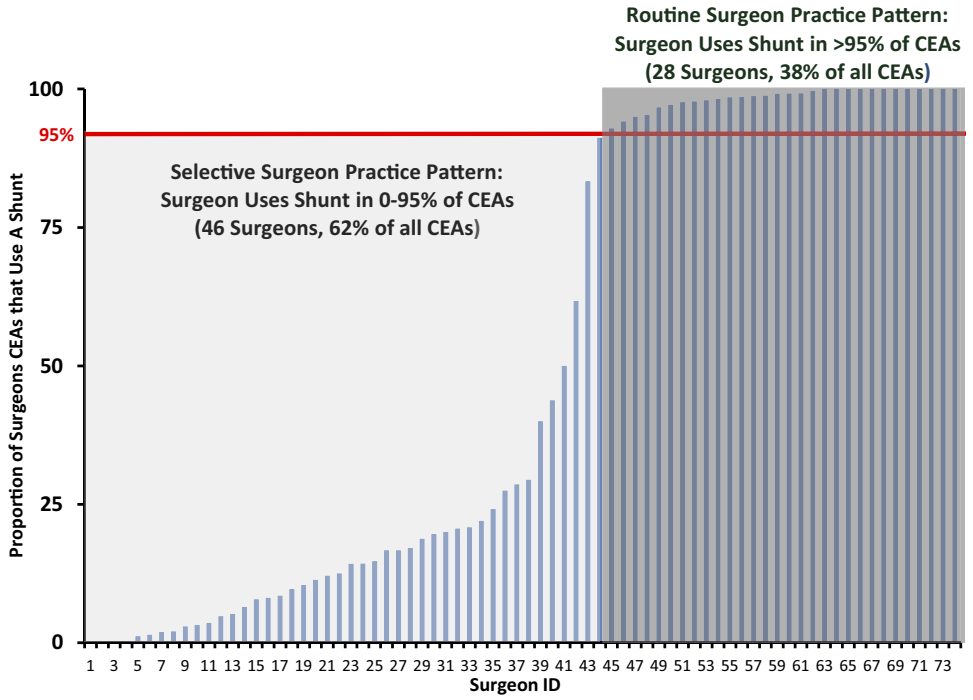

Fig 2. Surgeon practice patterns in shunt use in carotid endarterectomy (*CEA*).

Table II. A, Rate of 30-day stroke or death after carotid endarterectomy (*CEA*) by contralateral carotid occlusion (*CCO*) status

	CEA with CCO (n = 353)		*CEA without CCO (n = 5279)*		
Variable	*No.*	*%*	*No.*	*%*	P[a]
30-day stroke	14	3.97	100	1.78	.002
30-day death	3	0.77	9	0.1	.471
30-day stroke or death	14	3.97	102	1.93	.007

[a] *P* value from Fisher exact test.

Table II. B, Rate of 30-day stroke or death after carotid endarterectomy (*CEA*) by contralateral carotid occlusion (*CCO*) status and surgeon practice pattern for shunt placement

	CEA with CCO (n = 353)				*CEA without CCO (n = 5279)*			
Variable	*No shunt No. (%)*	*Routine shunt No. (%)*	*Placed for indication No. (%)*	P[b]	*No shunt No. (%)*	*Routine shunt No. (%)*	*Placed for indication No. (%)*	P[b]
30-day stroke	4/118 (3.3)	7/173 (4.0)	3/62 (4.8)	.883	46/2824 (1.6)	41/2210 (1.8)	9/245 (3.7)	.016
30-day death	1/118 (0.1)	1/173 (0.1)	1/62 (0.1)	.759	12/2824 (0.1)	7/2210 (0.1)	2/245 (0.1)	.511
30-day stroke/death	4/118 (3.4)	7/173 (4.0)	3/62 (4.8)	.883	48/2824 (1.7)	44/2210 (1.9)	10/245 (4.1)	.032

[b] *P* value from Fisher exact test.

differences in rates of 30-day stroke or death across categories of shunt use: no shunt, 3.4%; routine shunt, 4.1%; shunt for indication, 4.8% ($P = .8$, Table II). Patient characteristics between the three categories of shunt use did not vary significantly, and therefore, the predicted 30-day stroke or death rate risk across the three groups was not different: no shunt, 3.4%; routine shunt, 4.0%; and shunt for indication, 4.3% ($P = .891$). The O/E ratios (95% CIs) were similar across categories of shunt use: no shunt, 1.0 (0.3-2.4); routine shunt, 1.0

Table III. Rate of 30-day stroke or death in patients undergoing carotid endarterectomy (*CEA*) by surgeon practice pattern (surgeon shunts routinely, surgeon shunts selectively) and contralateral carotid occlusion (*CCO*) status

	CEA with CCO (n = 353)			*CEA without CCO (n = 5279)*		
Variable	*Shunts routinely No. (%)*	*Shunts selectively No. (%)*	P[a]	*Shunts routinely No. (%)*	*Shunts selectively No. (%)*	P[a]
30-day stroke	2/138	12/215	.027	35/1992	64/3287	.471
30-day death	1/138	2/215	.443	2/1992	4/3287	.636
30-day stroke/death	2/138 (1.5%)	12/215 (5.6%)	.054	36/1992 (1.81%)	66/3287 (2.02%)	.587

[a]*P* value from Fisher's exact test.

(0.4-2.4); and shunt for indication, 1.1 (0.3-3.0). These results showed that when we adjusted for patient characteristics, there were no significant differences in rates of 30-day stroke or death across categories of shunt use.

For comparison, rates of 30-day stroke or death across categories of shunt in patients without CCO are reported in Table II. The risk of 30-day stroke or death was significantly higher in patients in whom a shunt is placed for an indication (4.1%) compared with routinely placed shunts (1.9%) or patients in whom shunts were not placed (1.7%; $P = .03$).

Rate of 30-day stroke or death by surgeon practice pattern in shunt use. As shown in Fig 2, 46 of the 74 surgeons in our data set placed shunts selectively. Selective surgeons performed 62% of all CEAs in our data set, including 215 of the 353 (61%) CEAs with CCOs in our study. Of the 46 selective surgeons, 40 (87%) used a shunt in <30% of their CEAs. Conversely, 28 surgeons routinely shunted, and these surgeons performed 38% of all CEAs in our data, including 137 of the 353 (39%) CEAs with CCO in our study.

Surgeons who routinely used shunts in all their CEAs had a 30-day stroke or death rate of 1.5% in patients with CCOs, which was significantly lower than the rate of 5.6% in surgeons who used shunts selectively ($P = .05$; Table III). This difference was unlikely to be secondary to differences in patient characteristics between the two cohorts, because predicted risks according to patient characteristics were similar between these groups (3.9% vs 3.9%, $P = .961$), and patient characteristics associated with stroke or death were also similar in both groups (Table IV). The O/E ratio was >1 in patients undergoing selective shunting (1.4; 95% CI, 1.1-1.7), indicating higher than expected stroke risk. However, the O/E ratio was <1 for surgeons who placed shunts routinely (0.4; 95% CI, 0.2-0.9), indicating lower than expected risk of stroke or death according to preoperative patient characteristics.

Finally, we examined the rate of 30-day stroke or death by shunt use and surgeon practice pattern (Fig 3). Surgeons classified as "routine" shunters had the lowest overall rate of 30-day stroke or death when they placed a shunt (1.5%, Fig 3). Surgeons classified as "selective" shunters had a rate of 30-day stroke or death of 3.4% when they chose not to place a shunt in patients with CCO. The rate of 30-day stroke or death was highest (7.6%) for selective surgeons who chose to place a shunt during a CEA with CCO. As with our previous results, these differences are not likely to be due to differences in patient characteristics, because predicted risks of 30-day stroke or death did not vary significantly across groups (4.0%, 3.4%, 4.3%, respectively, Fig 3). When we calculated O/E ratios, we found that "routine" surgeons who shunted routinely performed slightly better than expected (0.4; 95% CI, 0.2-0.8), "selective" surgeons who did not shunt performed as expected (0.9; 95% CI, 0.7-1.2), and "selective" surgeons who placed a shunt performed slightly worse than expected (1.7; 95% CI, 1.2-2.1; $P = .05$ for trend across O/E ratios).

Table IV. Factors associated with 30-day stroke or death, by surgeon practice pattern

Variable	*Shunts selectively (%)*	*Shunts routinely (%)*	P
Age >80 years	14.9	11.7	.494
Aspirin or clopidogrel use	87.0	91.0	.182
Congestive heart failure	7.5	8.8	.665
Urgent procedure	10.2	13.9	.3
Cortical ipsilateral symptoms	7.4	5.1	.688

Finally, we performed a sensitivity analysis around our definition of "selective" shunt placement (95% of all CEAs) to examine if our findings were due to adverse events occurring in selective surgeons who placed a shunt frequently, such as in 30%, 50% or 90% of their CEAs. As shown in the Appendix (online only), our results did not change if we eliminated from the analysis any CEA in the setting of a CCO, wherein a "selective" surgeon placed a shunt in more than 30%, 50%, or 90% of non-CCO cases. This finding reflects the fact that the operations in most patients who underwent surgery in the setting of a CCO were performed by surgeons who clustered at the lower (<30%) and higher (>95%) ends of practice patterns. Only 11 CEAs with CCO (3% of the total) were performed by surgeons who shunted between 30% and 95% of their cases, and none of these patients experienced postoperative stroke or death.

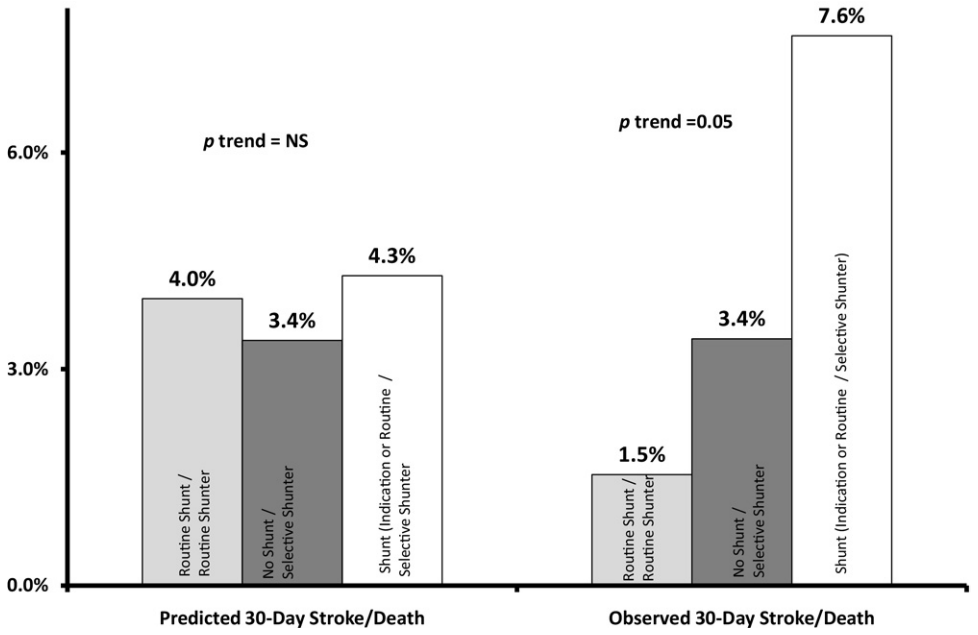

Fig 3. Predicted and observed 30-day stroke and death rate in patients with a contralateral carotid occlusion by shunt type and surgeon practice pattern.

DISCUSSION

Within our series of 353 primary CEAs performed in patients with CCO, the risk of 30-day stroke or death was higher in patients with CCO than in patients without CCO. Further, our data indicate that surgeons who placed shunts routinely had low rates of 30-day stroke or death when they placed a shunt, and surgeons who did not routinely use a shunt and performed CEA in the setting of CCO without a shunt also had low rates of 30-day stroke or death, but only when they did not place a shunt. The highest risk-adjusted chance of stroke or death occurred when surgeons who did not typically use a shunt placed a shunt during CEA in the setting of a CCO. Therefore, surgeons should consider their own practice pattern in shunt use preoperatively when faced with a patient who may require shunt placement.

The marginal risk imparted in CEA when the contralateral carotid artery is occluded has long been a topic of debate among vascular surgeons. Secondary data analyses from the North American Symptomatic Carotid Endarterectomy Trial (NASCET)[16,17] and the Asymptomatic Carotid Atherosclerosis Study (ACAS)[18] demonstrated increased rates of stroke or death among patients with CCO undergoing CEA. However in 2007, Dalainas et al[19] studied 2959 CEAs, 373 of which were performed in patients with CCO, and found no significant difference in perioperative stroke or death between patients with and without CCO. A similar-sized study performed by Rockman et al[14,15] also found similar rates of perioperative stroke or death between patients with and without CCO. Most studies have found little difference in outcomes after CEA among patients with CCO (Table V, *A*).

The role of shunt placement during CEA is also widely debated. Several prior series and a recently updated meta-analysis of randomized trials found no significant difference in outcomes after CEA among surgeons who routinely shunt and those who selectively shunt.[34] In the subset of CEAs with CCO, multiple observational studies have also found no impact of shunting on stroke or death after CEA with CCO (Table V, *A-C*).

Our results demonstrate an increased risk of stroke or death for CEA performed in the presence of CCO and that surgeons who shunt infrequently incur an increased risk of stroke when shunting is performed. Debate regarding the influence of these two covariates (CCO status and shunt use) on the stroke and death risk will undoubtedly continue. Our study adds to the current debate in two ways:

First, our study represents a large number of patients undergoing CEA with CCO in a real-world setting of mixed academic and community practice.

Second, our study indicates that surgeons who routinely place shunts during all their CEAs have better results than surgeons who place shunts selectively in the setting of a CCO, a novel observation in carotid surgery.

We believe a relationship may exist between the routine performance of a technically demanding process of care in surgery and better outcomes. Relationships such as these have multiple precedents in surgery. For example, the use of left interior mammary artery grafts during coronary artery bypass grafting and routine cholangiography during laparoscopic cholecystectomy[35,36] are both commonly referenced examples of the association between routine performance of complex processes of care with better surgical outcomes. Although indirect, our data suggest that the surgeons who perform shunt placement routinely are those who are most likely to perform it safely. Conversely, if an unplanned shunt is required

Table V. A, Outcomes between carotid endarterectomy (CEA) patients with and without contralateral carotid occlusion (*CCO*), in the presence or absence of a shunt

			Stroke/death rate in CCO		*Comparison of 30-day stroke/death*			*Stroke/death rate in non-CCO*		*Comparison of 30-day stroke/death*
Author (year)	*CCO cases* No.	*CCO cases using shunt* % (No.)	*Shunt* % (No.)	*No Shunt* % (No.)	*Shunt vs no shunt*	*Non-CCO cases* (%)	*Non-CCO cases using shunt* % (No.)	*Shunt* % (No.)	*No shunt* % (No.)	*b/w CCO and non-CCO*[a]
Locati[c,20] (2000)	198	83.3 (165)	4.2 (7)	3.0 (1)	NS	1068	8.9 (96)	2.3 (25)		NS
Ballotta[d,13] (2002)	68	52.9 (36)	0	6.3 (2)	NS	268	4.8 (13)	23.1 (3)	0	NS[b]
Schneider[d,21] (2002)	57	55 (31)	0	0	NS	507	13 (66)	7.6 (5)	0	NS[b]
Cinar[9] (2004)	55	10.9 (6)	50 (3)	0	<.001	374	9.1 (34)	8.8 (3)	0.9 (3)	NS[b]
Ballotta[22] (2004)	135	54 (73)	0	4.8 (3)	NS	38	15.7 (6)	0[f]		NS
Fitzpatrick[23] (2005)	16	68.8 (11)	9.1 (1)	0	NS	154	46.7 (72)	2.6 (4)[f]		NS
Ballotta[c,13] (2002)	68	52.9 (36)	1.4 (1)[f]			268	4.8 (13)	0.7 (2)[f]		NS[b]
Schneider[c,21] (2002)	57	55 (31)	1.8 (1)[f]			507	13 (66)	0.2 (1)[f]		NS[b]
Pulli[24] (2002)	82	25.6 (21)	2.4[f]			1242	6.9 (86)	1.4[f]		NS
Rockman[d,14,15] (2002, 2004)	338	66.2 (224)	3.0[f]			2082	27.3 (568)	2.1[f]		NS
Rockman[c,14,15] (2002, 2004)	338	66.2 (224)	0.6 (2)[f]			2082	27.3 (568)	0.1 (2)[f]		NS[b]
Domenig[25] (2003)	112	82.1 (92)	3.6 (4)[f]			1752	76.9 (1348)	1.9 (33)[f]		NS
Bellosta[26] (2006)	36	100	8.3 (3)[f]			706	100	0.42 (3)[f]		<.001[a]
Dalainas[19] (2007)	373	28.7 (107)	4.0 (15)[f]			2959	7.1 (210)	3.6 (107)[f]		NS

[a]Doesn't report. Stroke/death rate by shunt use or shunt use was 0% or 100%.
[b]Data extracted/combined from original article and assessed by this author using χ^2 with Fisher's exact test.
[c]Rates reported include transient ischemic attack.
[d]Complication rates reflect perioperative stroke only (mortality excluded).
[e]Complication rates reflect perioperative mortality only (stroke excluded).
[f]Studies did not provide data about shunt use.

for a specific indication in a patient with CCO, the infrequent shunt user had a substantially higher stroke/death rate.

Do our results suggest that shunt placement should be always be performed in CEA in the setting of CCO? We believe the answer is no. Rather, we believe our data suggest that the safest operation a surgeon can provide in the setting of a CCO is the operation that the surgeon would perform *without* the CCO being present. In other words, surgeons who shunt routinely fared best when they routinely placed shunts, and selective surgeons, on average, obtained the best results when they performed CEA in the way they most commonly performed the operation—without a shunt. We believe that surgeons can use our study to inform their preoperative decision making when faced with a patient likely to need a shunt, such as a patient with a CCO and an incomplete circle of Willis. In this setting, selective surgeons may choose to use strategies to limit the need for shunting, such as permissive hypertension, or refer the patient to a colleague who places shunts commonly. However, our study is small and will need to be replicated in larger settings before these conclusions are made.

Our study has limitations. Many will argue that our study, which is observational in nature, cannot fully account for patient differences or intraoperative events that led surgeons who do not usually shunt to place a shunt during a high-risk CEA. And although our observational data set does not obviate bias or confounding as a randomized trial might, our validated multivariable risk model fails to demonstrate any significant differences in patient characteristics that may explain our findings.

Second, our designation of surgeon practice pattern was established using data from the surgeon's practice pattern not in the setting of a CCO, and most surgeons designated as "selective" shunters were indeed selective (ie, shunted infrequently) in the use of this process of care. Many believe that the use of a shunt in 90% of cases more closely represents "routine" use. However, our sensitivity analyses of the effect of different cut points, such as 30%, 50%, 80%, and 90%, found little difference in the direction or magnitude of effect of our findings.

Third, the use of neuromonitoring differs across surgeons: some use EEG, others awake CEA, and still others use stump pressure as an indicator to place a "shunt for indication." We found no systematic evidence that these choices varied dramatically by surgeon practice pattern, but the nonrandomized nature of this covariate could potentially introduce bias.

Fourth, given the nonrandomized nature of our data set, we are unable to infer what might have occurred if a selective surgeon had chosen not to place a shunt during one of the cases in which he or she shunted for an indication.

Finally, beyond the debates surrounding the technical points of carotid surgery, all interested parties (surgeons, payers, and patients) agree that procedure-specific quality measures are needed to most effectively measure and improve performance.[37] At the outset of this project, we hypothesized that shunt use would be associated with better outcomes for CEA in the setting of CCO. It seemed to be a reasonable presumption that shunt use in the setting

Table V. B, Comparison of stroke/death rates in selective vs routine shunting

Author (year)	*No. in selective shunt (No. shunted)*	*Stroke/death in selective shunt % (No.)*	*Routine shunt, No.*	*Stroke/death rate in routine shunt % (No.)*	P *Selective vs routine*	*Stroke/death in shunt (%)*	*Stroke/death in no shunt (%)*	P *Shunt vs no shunt*[b]
Woodworth[27] (2007)	194 (41)	1 (2)[a]	1217	3.9 (47)	.04	3.8	0.7	.047
AbuRahma[28] (2010)	102 (29)	2 (2)	98	0 (0)	NS	0	2.7	NS
Grga[29] (2001)	144 (43)	3.5 (5)	170	0.6% (1)	NS[b]	0.9	4.0	NS
Nguyen[30] (2005)	117 (22)	0.8 (1)	878	0.7% (6)	NS[b]	0.8	0	NS
Salvian[c,31] (1997)	213 (34)	0.5 (1)	92	4.4% (4)	NS	3.2	0.6	NS

[a]Complication rates reflect perioperative stroke only (mortality excluded).
[b]In many cases, data were extracted from original article and assessed by this author using χ^2 with Fisher exact tests.
[c]Complication rates reflect perioperative major stroke only (mortality and minor stroke [resolved within 30 days] were excluded).

Table V. C, Comparison of stroke/death rate in shunt vs no shunt[c]

Author (year)	*Shunted % (No.)*	*Stroke/death % (No.)*	*No shunt % (No.)*	*Stroke/death % (No.)*
Chang[32] (2000)	4.1 (112)	2.7 (3)	95.5 (2612)	1.1 (28)[b]
Ballotta[12] (2003)	(43)	2.3 (1)	(581)	0.5 (3)[b]
Palombo[33] (2007)	50 (48)	0 (0)	50 (48)	0 (0)[b]
Ballotta[5] (2010)	16.3 (312)	3.2 (1)[a]	83.7 (1602)	0.62 (10)[b]

[a]Complication rates reflect perioperative stroke only (mortality excluded).
[b]In many cases, data were extracted from original article and assessed by this author using χ^2 with Fisher exact tests. The *P* values for stroke/death for shunt vs no shunt were not statistically significant.
[c]Complication rates reflect perioperative major stroke only (mortality and minor stroke [resolved within 30 days] were excluded).

of CCO could potentially serve as a reasonable procedure-specific quality indicator in vascular surgery. However, as outlined above, our registry data refuted this hypothesis, leading us to conclude that shunt use is not a useful quality measure because surgeons can achieve excellent outcomes with or without using a shunt. This process illustrates the need for vascular surgeons to become active participants in developing and vetting quality measures, a process that will often require detailed clinical data from representative, real-world practice.

CONCLUSIONS

Within our multicenter registry, the risk of 30-day stroke was significantly higher in patients with CCO. Further, although shunt use itself was not directly associated with lower rates of 30-day stroke/death, surgeons who use a shunt infrequently during any CEA have higher rates of stroke/death when treating patients with a CCO with a shunt. Our results suggest that shunt use in CEA with CCO is associated with a lower rate stroke/death, but only if the surgeon uses a shunt as part of his or her routine practice.

AUTHOR CONTRIBUTIONS

Conception and design: PG, SS, JC
Analysis and interpretation: PG,JW, SS, JC
Data collection: PG, JW, SS
Writing the article: PG, SS, JW
Critical revision of the article: DS, VP, PS, BN
Final approval of the article: PG, JW, SS, DS, VP, PS, BN, JC
Statistical analysis: PG, SS, BN, JC
Obtained funding: PG, JC
Overall responsibility: PG

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Appendix (online only)

The rates for 30-day stroke and death are shown in patients with a contralateral carotid occlusion (*CCO*) by shunt type and surgeon practice pattern, excluding selective surgeons who shunt >50% of patients. Findings were similar for 30% and 90% cut points.